Available online at www.sciencedirect.com

SciVerse ScienceDirect

Procedia Engineering 26 (2011) 869 – 875

Procedia Engineering

www.elsevier.com/locate/procedia

First International Symposium on Mine Safety Science and Engineering

Research on integration of roadway excavation, bolting, support, and detection

Chen Jia-sheng[a], Gao Ming-zhong [b,]a*

[a]*School of Mechanical Engineering , Anhui University of Science and Technology, Huainan City 232001, China*
[b]*School of Energy and Safety, Anhui University of Science and Technology, Huainan City 232001, China*

Abstract

According to the situation that temporary support equipment is backward, new type temporary support equipment is developed. This temporary support equipment can support roof and front wall of roadway quickly, can reduce roof subsidence, roof fall accidents, front wall collapse, and labor intensity, and has high economic and wide application value. Integration ideas of roadway excavation, bolting, support, and detection is put forward, i.e. to make roadheader as a platform and combine new type temporary support equipment, new type bolter, and detection devices with roadheader to achieve reasonable dynamic roof support design and safe rapid roadway excavation.

Selection and/or peer-review under responsibility of China Academy of Safety Science and Technology, China University of Mining and Technology(Beijing), McGill University and University of Wollongong.

Keywords: new type temporary support equipment; integration; roadheader; detection equipment; safety and high efficiency

1. Introduction

Developing directions of roadway excavation are:

- To improve support design methods, to eliminate backward support methods, and reduce the occurrence of roof accidents.
- To improve the performance of equipments and reduce labor intensity.
- To develop multifunctional equipments.

* Corresponding author. Tel.: 13655616036.
E-mail address: chenjiasheng200306@tom.com.

1877-7058 © 2011 Published by Elsevier Ltd. Open access under CC BY-NC-ND license.
doi:10.1016/j.proeng.2011.11.2249

- To accelerate the tunneling rate can solve succeeding tension between mining and excavation, and mine productivity and efficiency can be improved greatly.
- New technology need to be developed to overcome new difficulties arising with the increase of mining depth.

2. The status quo of temporary support and permanent support of roadway

There are mainly two kinds of temporary support in coal mines, single hydraulic props with wood blocks are used at roadways which are supported by bolts, and moving forward beams are used at roadways which are supported by steel frames.

The disadvantages of the above two kinds of temporary support are:

- They produce small support force and slow support speed.
- Roof can't be supported in time so that roof subsidence and accidents often happen.
- Miners' work is arduous, temporary support can not meet the needs of rapid excavation.
- They result in disorders between mining and excavation because of low excavation speed [1].
- Tunneling loop distance is determined by experience, too.

Currently the method of engineering analogy is commonly used in permanent support design at most of coal mine roadways. Roof type and structure often change frequently in the same layer at the same tunnel, but roof type and structure can not be detected in time, so support design can't be changed in time. Sometimes inadequate supporting strength results in roof accidents. Sometimes excessive supporting strength results in waste of supporting materials, time, and labor. If the detection devices and tunneling machine are combined together, roof type and structure are detected in real time, roadway support design can be corrected without delay, roof stability is ensured, safe work environment is created for miners, and rapid tunneling is ensured.

3. Development of a new type of roadway temporary support equipment

3.1. Characteristics of suspension hydraulic temporary support equipment

1. This equipment can be operated easily (the operator can operate handles of direction valves in safe place), it can be moved quickly and smoothly, its supporting area is large, it can reduce roof subsidence, roof fall accidents, front wall collapse, and labor intensity. The newly-exposed roof can be supported without delay.
2. Hydraulic source of roadheader can be used as power source of the equipment, roadheader's structure do not need to be transformed. This temporary support equipment does not interfere with the operation of roadheader, only need an inlet pipe and a return pipe from roadheader.
3. This equipment can be adapted to steeply inclined roadway, it can also action quickly in steeply inclined roadway.
4. This equipment makes full use of space at the top of roadway. It does not affect other processes of tunneling. Its installation, dismantle, and maintenance is convenient, its structure is simple, its manufacture is easy. It has high economic and wide application value.
5. Two or three elevating platforms are designed so that tunneling loop distance can be adjusted according to the situation of roof. One loop distance can be a row to three rows of bolt. If bolt row distance is calculated by 0.8–1.0 meter, maximum loop distance can be 2.4–3.0 meters. The tunneling speed can be increased, and the imbalance between excavation and mining caused by low tunneling speed at many mines can be solved.

6. This equipment can replace workers to lift roof support materials and reduce labor intensity. Two ends of special suspension I-beams are cut into slope, so the gradient of the suspension beams can be adjusted to adapt to changes of roadway slope. The shape of elevating platform's canopy can be changed to adapt to roadways with different cross sections.
7. If rock is hard and blasting is required, the front board to shield wall can be opened and protecting plate can be hung on the front board so that hydraulic components on the temporary support equipment, methane sensor, wind tubing, and other equipments can be prevented from blasting.

3.2. The main components and function of suspension hydraulic temporary support equipment

Hydraulic temporary support equipment consists of steel structural components and hydraulic system as shown in Figure 1.

Steel structural components are special suspension I-beams, support platform, elevating platforms, board to shield front wall, moving trolley, non-slip fixer, connecting base, and so on. The hydraulic system consists of hydraulic cylinders, hydraulic control valves, and hydraulic auxiliary components (hose and tube connectors, etc.).

Steel structural components and hydraulic system are connected through pins and bolts, etc. Tubes are connected through quick connectors and U-clamps.

1. *Special suspension I-beams:* These beams are installed at the exposed ends of the two middle lines of bolts in roadway when roof is supported by bolts, are installed on the support beams in the middle of roadway when roof is supported by steel frames. Temporary support equipment is suspended and fixed on suspension I-beams, and can move along the I-beams.
2. *Supporting platform:* It is used as supporting body for elevating platforms, its fore-end is hinged to board to shield front wall, its lower part is hinged to leg cylinder and leg retractable cylinder, its back-end is hinged to moving trolley.
3. *Elevating platforms:* They can lift and descend through hydraulic cylinders, its canopy can touch and support the roof, two or three elevating platforms are designed so that tunneling loop distance can be adjusted according to the situation of roof and rapid tunneling can be achieved.
4. *Board to shield front wall:* It can support front wall temporarily and prevent collapse of front wall, the hook on the board can hook non-slip fixer and help to suspend temporary support equipment.
5. *Moving trolley:* It is made of welded steel plate, is suspended through a few wheels on the special suspension I-beams, and is hinged to supporting platform and hydraulic cylinders through bolts and nuts. Pushing cylinder can push moving trolley to drive temporary support equipment to move.
6. *Non-slip fixed clamp:* It can prevent the temporary support equipment from sliding down from the suspension I-beams.
7. *Connecting base:* It is fixed to suspension I-beams through bolts and nuts, its lug can make itself suspend on the suspension I-beams when the pushing cylinder contracts forward.

3.3. The working procedure of suspension hydraulic temporary support equipment

Temporary support equipment can be operated according to the following steps.

Step1. Amplitude cylinder of supporting platform contracts to make supporting platform rotate and descend, and miners make support materials fixed to the canopies of elevating platforms.
Step2. Amplitude cylinder of supporting platform expands to make supporting platform rotate and parallel with roadway roof.
Step3. Pushing cylinder expands to push the support platform forward.
Step4. Elevating platforms lift to touch and support the roadway roof.

Step5. Leg amplitude cylinder expands to make leg cylinder rotate and perpendicular to supporting platform, then leg cylinder contacts to tough roadway floor.

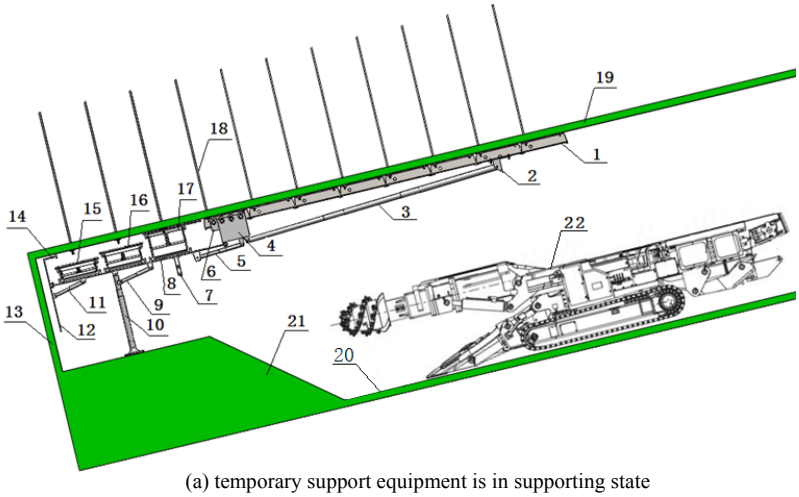
Step6. To drill roof holes and install roof bolts or install steel frames.

Step7. Elevating platforms descend, and suspension I-beams are installed, then leg cylinder is packed up.

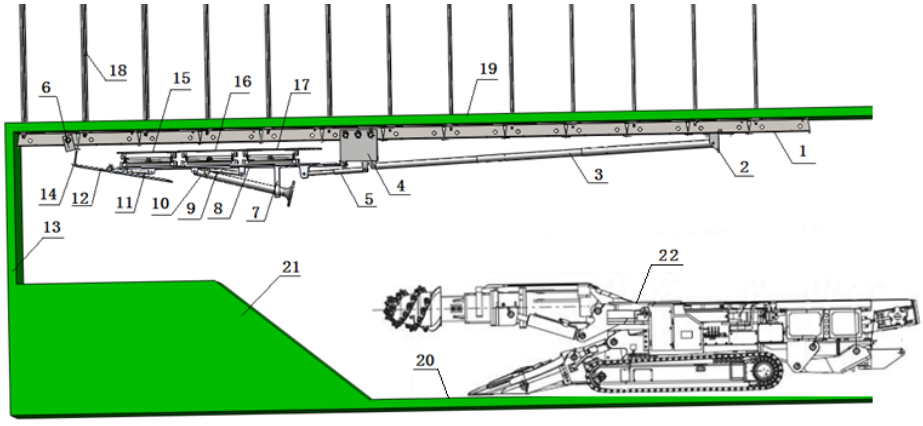
Step8. Non-slip fixed clamp is dismantled, and installed on suspension I-beams ahead. Pushing cylinder contracts to make supporting platform move backward and expands to make front hook hitch the non-slip fixed clamp.

Step9. Bolts and nuts which connects connecting base to suspension I-beams are dismantled, pushing cylinder contracts to make connecting base move forward, then connecting base is fixed with bolts and nuts.

Step10. Roadheader cuts coal or rock.



(a) temporary support equipment is in supporting state



(b) temporary support equipment is retracted

1–special suspension I-beams; 2–connecting base; 3–pushing cylinder; 4–moving trolley; 5–amplitude cylinder of supporting platform; 6–non-slip fixed clamp; 7–fixed clamp; 8–supporting platform; 9–leg amplitude cylinder; 10–leg cylinder; 11–amplitude cylinder of board to shield front wall; 12–board to shield front wall; 13–wall in roadway; 14–hook; 15–first elevating platform; 16–

second elevating platform; 17–third elevating platform; 18–roof bolt; 19–roadway roof; 20–roadway floor; 21–rock or coal in roadway; 22–roadheader

Figure 1. system layout of the temporary support equipment in bolting roadway

4. Matching of bolter and roadheader

There are mainly two types of bolters: pneumatic bolter and hydraulic bolter.

Pneumatic bolter is powered by compressed air. Pneumatic bolter can be divided into rotary impact bolter and rotary bolter according to approaches of breaking rocks. Rotary impact bolter is also called air-leg rock drilling machine, such bolter drills rocks through pneumatic impact, its advantages are quick drilling speed, light weight, convenient handling, and easy operation, etc. Its disadvantages are loud noise, more difficult working environment, affecting workers' health, and low drilling efficiency when air pressure is low.

Currently single pneumatic rotary bolter are used widely in China coal mines, pneumatic rotary bolter is mainly made of gas motor, legs, and arm, its weight is lessened and easy to be moved and operated because its leg is made of new materials of glass steel. It can install resin bolt and cement mortar bolt, but drilling efficiency is low when air pressure is inadequate.

Hydraulic bolter can overcome the difficulty of low drilling speed because of low air pressure for pneumatic bolter, and it has advantages of high working pressure, high torque, high drilling speed, and low noise, especially in hard rocks[2,3,4,5].

New type bolter should be combined with geological drilling rig, and can drill both bolt holes and geological holes.

Roadheaders have the advantages of continuous excavation, high efficiency, high speed, safety, no vibrations or damage on the surrounding rock, and good working environment, etc., so roadheaders are used widely. New type bolters should be developed and matched with roadheaders, hydraulic source of roadheaders can be used as power source of bolters. Roadheaders are used as platforms of installation and operation for bolters, bolters needn't to be moved by workers, so rapid support, excavation and detection are achieved.

5. Matching of roadheader and detection equipment of roof type and structure

Nowadays, roadway roof support is designed by experience, and designing method is called qualitative design because roof type and structure are uncertain.

Qualitative design has many disadvantages:

- Inadequate supporting strength results in roof accidents.
- Excessive supporting strength results in waste of supporting materials, time, and labor, so tunneling efficiency is reduced.
- Excessive supporting strength often results in roof overhanging area too large and causes rock burst, methane overruns due to inadequate air flow at upper corner of coalface.

If roof type and structure is detected, above disadvantages of "qualitative design" can be overcome. There are some kinds of roof detection methods, roof rock type and structure can also be detected in real time through detecting penetration rate, rotational speed, thrust, and torque of bolter, these drilling parameters can provide dynamic "quantitative design" with reliable geological basis. Through roof detection, supporting design and roof management can be guided, supporting can meet needs of safety and production, roof accidents can be reduced, and safe working environment can be created for miners[6,7,8].

Rock drilling parameters have the following law. Specific energy of drilling E, thrust F, penetration rate v, rotational speed ω, and torque T satisfy the formula (1). Specific energy of drilling E is different for different rocks so that roof rock type and structure can be detected by detecting thrust F, penetration rate v, rotational speed ω, and torque T of bolter[9,10].

$$E = \frac{F}{A} + \frac{2\pi\omega T}{Av} \tag{1}$$

Where:

E = specific energy of drilling, psi
F = thrust, lbs
A = cross-sectional area of the hole, in^2
ω = rotational speed, rpm
T = torque, in-lbs
v = penetration rate, in/sec

Bolter combines with displacement sensor, thrust sensor, flow sensor, and pressure sensor to detect and transfer parameters of cylinder velocity, pushing force, oil pressure and flow of hydraulic system, torque and rotational speed of hydraulic motor to control center of roadheader. Through data processing of control center, roof rock type and structure can be determined, roadway roof support design can be corrected in real time, and drilling parameters can also be used to guide roof support design of coalface.

6. Conclusions

Suspension hydraulic temporary support equipment makes roadway temporary support processes mechanized, and working environment is improved greatly. This type of support equipment can generate appropriate initial supporting force on roof and front wall, supporting area is large, collapse accidents of roof and front wall can be reduced, and labor intensity can be reduced, too. This type of support equipment meets the requirements of high production and high efficiency of mines, and can produce great economic and social benefit.

Through detection of roof type and structure, the situation that roadway support is designed by experience in coal mines can be changed, and dynamic roadway roof support design is achieved. Through matching of bolter and geological drilling rig, and roadheader, safe rapid support and excavation is achieved.

References

[1] Li Ming-fa, Li Xiu-wei. Comparison and analysis of on-board temporary support and manual temporary support. *Coal Mine Safety*, 2010, 433(11): 99–101. (in Chinese)

[2] Zhao Zeng-hui, Zhang Jiang-zhong. Some recognitions on test of excavation and bolting integration. *Coal Technology*, 2006, 25(4): 49–51. (in Chinese)

[3] Sun Xu-wei. Analysis and study on development of integration of excavation and bolting technology. *Coal Mine Machinery*, 2010, 31(3): 49–51. (in Chinese)

[4] Zhao Xue-lei, Meng Guo-ying. Research and practice in key technology of rapid automate excavation and bolting support. *Coal Mine Machinery*, 2010, 31(12): 183–185. (in Chinese)

[5] Zhougan. Discussion on the current development of roof bolter. *Pneumatic Tools of Rock Drilling Machinery*, 2006 (3). (in Chinese)

[6] Teng Zi-jun. Real-time strata detection with drilling parameters instrument. *Coal Geology & Exploration*, 2000, 28 (2) : 58–60. (in Chinese)

[7] Jia Ming-kui. Research on roof falling mechanism of deteriorative stratas combination supported by bolts. *Rock and Soil Mechanics*. 2007, Vol. 28 No.7: 1343–1347. (in Chinese)

[8] Jia Ming-kui. Research on detection technique for inferior stratas combination. *Journal of China University of Mining & Technology*, Jan.2006, Vol.35 No.1. (in Chinese)

[9] Gerald L. Finfinger et al. An approach to identifying geological properties from roof bolter drilling parameters. *Proceedings 19th International Conference on Ground Control in Mining*, Aug 8–10, 2000, Morgantown, WV, USA.

[10] Syd S.peng et al. Mine roof geology information system: A method for quantitative void/fracture detection and estimation of rock strength for underground mine roof. http://www.coalage.com, May 2005.